REMARKS

Claims 43, 44, 76 and 78 are pending in the present application. In the Office Action dated March 11, 2003, the Examiner rejected claims 43, 44, 76 and 78 under 35 U.S.C. § 102(b) as anticipated by U.S. Patent No. 5,332,444 to George, *et al.*("George"). The examiner further rejected claims 43, 44, 76 and 78 as anticipated by U.S. Patent No. 5,723,384 to Park, *et al.* ("Park"). Applicants disagree with these grounds of rejection and wish to clarify various distinctions of applicants' invention over the cited art. Reconsideration of the invention is therefore requested in light of the present amendment and following remarks.

The disclosed embodiments of the invention will now be discussed in comparison to the prior art subject matter. Of course, the discussion of the disclosed embodiments and the discussion of the differences between the disclosed embodiments and the prior art subject matter, do not define the scope or interpretation of any of the claims. Instead, such discussed differences merely help the Examiner appreciate important claims distinctions discussed thereafter.

Applicant's invention exposes a conductive layer to an oxygen-inhibiting plasma prior to the formation of the another layer or layers on the conductive layer to substantially reduce the association of oxygen with the conductive layer during formation of the other layer or layers. By reducing the amount of oxygen associated with the conductive layer, the electrical characteristics of a semiconductor device including the conductive layer are improved.

Figures 4 and 5 illustrate in-process semiconductor devices being formed by a process according to one embodiment of the present invention. As mentioned in the specification, for the purposes of explanation the in-process semiconductor device is assumed to be a capacitor in the process of being constructed. In Figure 4, the capacitor includes a first conductive layer or 24, which may be formed from hemispherical silicon grain (HSG), formed over a substrate 22, and a dielectric 26 formed on the first conductive layer. In the examples of Figures 4 and 5, the dielectric 26 is formed from tantalum pentoxide Ta_2O_5. A second conductive layer 28 formed from tungsten nitride WN_x is then formed on the dielectric 26. The tungsten nitride layer 28 has a tendency to associate with oxygen, particularly if that layer is exposed to oxygen prior to a third conductive polysilicon layer 30 being formed on the tungsten nitride layer 28. During subsequent processing of the capacitor, the oxygen contained in the tungsten nitride layer 28 can combine with silicon from the polysilicon layer 30 to form an unwanted silicon dioxide layer 36 between the tungsten nitride layer 28 and the polysilicon layer

30. For example, a thermal process step such as the formation of a borophosphosilicate glass (BPSG) layer 34 over the polysilicon layer 30, which of course occurs after the formation of the polysilicon layer 30, may cause a reaction between the polysilicon layer 30 and the oxygen in the tungsten nitride layer 28 and thereby form the silicon dioxide layer 36.

Ideally, the HSG layer 24 forms a first plate of the capacitor, the tantalum pentoxide 26 forms the dielectric of the capacitor, and the tungsten nitride layer 28 and polysilicon layer 30 form the second plate of the capacitor. With the formation of silicon dioxide layer 36, however, the capacitor now includes a first capacitor corresponding to the HSG layer 24, tantalum pentoxide 26, and tungsten nitride layer 28, and a second capacitor in series with the first capacitor, with the second capacitor corresponding to the tungsten nitride layer 28, silicon dioxide layer 36, and polysilicon layer 30. These first and second capacitors connected in series have a combined capacitance that is less than that of the ideally formed capacitor. As will be understood by those skilled in the art, the thickness of the silicon dioxide layer 36 affects the value of the combined capacitance.

In the capacitor of Figure 4, the thickness of the silicon dioxide layer 36 is greatly reduced by exposing the tungsten nitride layer 28 to an oxygen-inhibiting agent prior to the formation of the polysilicon layer 30 to thereby greatly reduce the association of the tungsten nitride layer with oxygen. The silicon dioxide layer 36 in the embodiment of Figure 4 is less than 10 angstroms thick due to the oxygen-inhibiting agent, while in a conventional capacitor shown in Figure 3 the silicon dioxide layer 36 is about 10-40 angstroms thick. In the capacitor of Figure 5, the exposure of the tungsten nitride layer 28 to the oxygen-inhibiting agent eliminates the formation of the silicon dioxide layer 36 altogether.

The oxygen-inhibiting agent may be an N_2 and H_2 plasma, with the tungsten nitride layer 28 ideally being exposed to this plasma prior to exposing tungsten nitride layer to an atmosphere associated with the formation of the polysilicon layer 30 or prior to exposing the tungsten nitride layer to oxygen. As described in the specification, it is believed the exposure of the tungsten nitride layer 28 to the N_2 and H_2 plasma or any of the other oxygen-inhibiting agents stuffs the tungsten nitride layer grain boundaries with nitrogen or otherwise passivates the tungsten nitride layer, making the bonds at the grain boundaries less active and less likely to associate with oxygen. It should be noted that even if the tungsten nitride layer 28 is exposed oxygen, the layer may thereafter be exposed to a reducing atmosphere, such as silane gas SiH4, prior to formation of the polysilicon layer 30 to thereby reduce the oxygen content of the

tungsten nitride layer 28 and reduce the thickness of any silicon dioxide layer 36 thereafter formed.

In another embodiment discussed with reference to Figure 6, a first conductive layer such as a tungsten nitride layer 128 is deposited over a substrate 122 and a dielectric layer 126, such as a tantalum pentoxide layer, is deposited over the tungsten nitride layer. In this situation, the deposition of the tantalum pentoxide layer 126 may cause the tungsten nitride layer 128 to incorporate oxygen, reducing the capacitance of a capacitor including the tungsten nitride layer and tantalum pentoxide layer. Accordingly, in this embodiment of the invention, the tungsten nitride layer 128 is exposed to a N_2 and H_2 plasma or other oxygen-inhibiting agent before depositing the tantalum pentoxide layer 126. As previously described, the N_2 and H_2 plasma passivates the tungsten nitride layer 128 to thereby prevent oxygen from being incorporated within the tungsten nitride layer.

Another embodiment of the present invention is discussed with reference to Figures 7-10 in which and interposing layer 52 such as a tungsten nitride layer 52 is formed between a conductive line material 48 to enhance the electrical contact between the line material and the plug, promote adhesion of the line material within a container 50, prevent or slow the diffusion of materials across the tungsten nitride layer boundary, or serve some other purpose. As previously described, the tungsten nitride layer 52 may associate with oxygen after it is formed and subsequent thermal processes may result in the formation of an oxide layer 54 formed between the tungsten nitride layer 52 and the line material 48. Because the oxide layer 54 is an insulator, this layer will adversely affect the electrical connection between the line material 48 and the plug 46. By exposing the tungsten nitride layer 52 to an oxygen-inhibiting agent or a reducing atmosphere prior to formation of the line material 48, the thickness of the oxide layer 54 is reduced to a thickness of less than 10 angstroms or entirely eliminated as illustrated respectively in Figures 9 and 10. Thus, in all embodiments a conductive layer is exposed to an oxygen-inhibiting agent or reducing atmosphere prior to another layer being formed on the conductive layer to thereby reduce an ability of the conductive material to associate with oxygen.

The Examiner has cited the George reference. George is directed to a cleaning agent and a method wherein a metal surface having metal-containing contaminants is exposed to HMDS to form volatile metal-ligand complexes on the surface of the metal surface. The metal-ligand complexes thus formed are then removed from the surface by a sublimation process.

George does not disclose or fairly suggest the use of phosphine or methylsilane as a passivating agent.

The Examiner has further cited the Park reference. Park discloses a method for forming a capacitor in a semiconductor device that includes the formation of first and second insulating layers with a first contact hole extending through to a semiconductor substrate, then patterning a first conductive layer to form a pedestal extending away from the substrate, patterning a third insulating layer to form an upper portion of the lower electrode from a tungsten nitride thin film, and finally forming an undercut beneath the pedestal portion by wet-etching the second insulating layer. In particular, the specification discloses that the tungsten nitride thin film is formed using a chemical vapor deposition (CVD) process that utilizes a deposition gas containing a tungsten compound, and a reaction gas. The reaction gas may include diborane (B_2H_6) (col. 4, lines 10-20). Applicant notes that diborane is used as a reaction gas in order to assist in the formation of the tungsten nitride thin film. The Park reference does not disclose or fairly suggest the use of diborane as a passivation agent.

Turning now to the claims, differences between the claim language and the applied art will be specifically pointed out. Claim 43, as amended, recites in pertinent part, "A method of passivating a multilayer conductive structure, comprising...layering a first conductive material...introducing said first conductive material to a material selected from the group consisting of *diborane, phosphine, methylsilane, and various combinations thereof* ...". (Emphasis added). The George reference does not disclose the use of the foregoing compounds as a passivating agent. The Park reference also fails to disclose the foregoing compounds for passvating a conductive structure. Claim 43 is therefore allowable over the cited art. Claims depending from claim 43 are also allowable based upon the allowability of the base claim and further in view of the additional limitations recited in the dependent claims.

Claim 76, as amended, recites in pertinent part, "A method of passivating a multilayer conductive structure, comprising...layering a first conductive material...introducing said first conductive material to a material selected from the group consisting of *phosphine, methylsilane, and various combinations thereof* ...". (Emphasis added). Again, the applied references fail to disclose this. Claim 76 is therefore allowable over the cited art. Claims depending from claim 76 are also allowable based upon the allowability of the base claim and further in view of the additional limitations recited in the dependent claims.

Finally, claim 78, as amended, recites in pertinent part, "A method of passivating a multilayer conductive structure, comprising...layering a first conductive material...introducing the first conductive material to a material selected from the group consisting of *borane, phosphine, methylsilane, and various combinations thereof* ...". (Emphasis added). Yet again, the applied references fail to disclose this. Claim 78 is therefore allowable over the cited art. Claims depending from claim 76 are also allowable based upon the allowability of the base claim and further in view of the additional limitations recited in the dependent claims.

Claims 81-85 are new. No new matter has been added.

All of the claims remaining in the application are now clearly allowable. Favorable consideration and a Notice of Allowance are earnestly solicited.

Respectfully submitted,

DORSEY & WHITNEY LLP

Steven H. Arterberry
Registration No. 46,314

SHA:tlm

Enclosures:
Postcard
Check
Fee Transmittal Sheet (+ copy)

1420 Fifth Avenue, Suite 3400
Seattle, WA 98101-4010
(206) 903-8800 (telephone)
(206) 903-8820 (fax)